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ORIGINAL ARTICLE

Mapping biosafety level 3 (BSL-3) and BSL-4 laboratories for public health threats reduction

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Abstract

Aim No international organization has a comprehensive register or global oversight of Biosafety Level 3 (BSL-3)/BSL-4 laboratories. Different countries use different standards for designation of pathogens and laboratories. This study aimed to investigate the global geospatial distribution of BSL-3 and BSL-4 laboratories to inform biosafety efforts.

Subject and methodology Publicly available data were used to collect data on BSL-3 and BSL-4 laboratories globally. Further details of each laboratory, including the locations (i.e., latitude/longitude coordinates) and pathogens worked on, were collected manually from Google Maps and the official Web pages of laboratories, respectively. The most recent and highest biosafety level was used to classify the laboratories as BSL3 or BSL4. Other, country-level indicators were analyzed and were collected from the World Bank, the Worldometer, and the 2021 Global Health Security Index Report. The presence of dual-use research concerns guidelines in a country was reviewed for each country reporting at least one BSL-3 laboratory.

Results We identified 3515 BSL-3 laboratories in 149 countries, with nearly half (47.1%) in the United States. Details on geolocations and pathogens they handled are publicly available for 955 of these labs. The United Kingdom had the highest rate ($N = 9$) of BSL-3 labs per million population, while Bangladesh had the lowest. High-income countries house 82% of these laboratories. There are 110 BSL-4 laboratories in 34 middle- and high-income countries, and 46% are in the WHO's Europe region. Notably, from the health security index perspective, 91.6% of countries with at least one BSL-3 laboratory lack guidelines for dual-use research of concern.

Conclusion BSL-3 and BSL-4 laboratories are unevenly distributed by income level, population density, and health security index. More than 90% of the countries with at least one BSL3 laboratory have no oversight/regulations regarding dual-use research. This study can inform future global governance efforts to improve biosafety.

Keywords Biosafety level 3 · Biosafety level 4 · Geospatial epidemiology

Introduction

Enhanced pathogens of pandemic potential, which are present in Biosafety Level 3 (BSL-3) and Biosafety Level 4 (BSL-4) laboratories, are a concern as they can easily cross international boundaries and cause epidemics or pandemics (McCloskey et al. 2014; National Institute of Health 2023). High-containment biosafety facilities, including BSL-3 and BSL-4 laboratories, are indispensable during emergencies of infectious disease outbreaks, with their functions ranging from the identification of causative agents, pathogen genomic sequencing, rapid diagnostics to the development of effective vaccines and drugs for treatment (Le Duc and Ksiazek 2015; Xia and Yuan 2022). For instance, the BSL-3 and BSL-4 biosafety laboratories were critical for diagnostics during epidemics

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of Ebola and the COVID-19 pandemic (Yeh et al. 2021). However, there has been speculation about the origin of SARS-COV-2, whether it may have accidentally originated from the Wuhan Institute of Virology, which was conducting coronavirus research (Young 2023). While known formal labs can be mapped and documented, there is no global mechanism to do so. Some of these labs may be disrupted during war or conflict, which may lead to biorisk to surrounding communities, so understanding the global distribution of these can improve biosafety. There is also a threat of clandestine or illegal labs, such as the one discovered in Reedley, California, in 2022 or the bioterrorist lab of the Rajneesh cult in Oregon in the 1980 s (MacIntyre 2023).

Despite ongoing efforts, there are no comprehensive global databases of documented labs at BSL-3 or BSL-4 levels, although the Global Biolabs project and the Decentralized Radical Autonomous Search Team Investigating COVID-19 (DRASTIC) have mapped some of these (Global BioLabs 2023). Further, new labs are being continually built, such as Russia's plan to build 15 BSL-4 laboratories (Russian News Agency 2021) in 2024, and the USA's National Bio and Agro-Defense Facility (NBAF) in Manhattan, Kansas State, which opened in 2023 to replace the long-standing facility on Plum Island (Department of Homeland Security 2023).

BSL-4 laboratories represent the highest containment laboratories tasked with handling the riskiest pathogens (Ficociello et al. 2023). Despite their small numbers, discrepancies persist in reporting the number of these laboratories. For instance, the World Health Organization (WHO) reported 43 BSL-4 laboratories (World Health Organization 2018), while Global Biolabs identified 69 planned, operational, and under-construction laboratories across 27 countries (Global BioLabs 2023). Other sources reported varying numbers of BSL-4 laboratories (Supplementary Information, Table 1).

BSL-3 laboratories may be part of research institutions, government laboratories, pharmaceutical industries, clinical/hospital service-providing institutions owned by universities, and research organizations. Schuerger et al. (2022) mapped BSL-3 laboratories by publication outputs and found that 434 organizations own at least one BSL-3 laboratory, with two-thirds of these labs from Europe and North America. However, these studies do not include laboratory names or locations, focusing only on the number of BSL-3 or BSL-4 laboratories.

A further challenge is that BSL-3 or BSL-4 laboratories may change their name or biosafety level over time. For instance, the "Georgia Central Public Health Reference Laboratory" was renamed to "Richard G. Lugar Center for Public Health Research" in 2013 (Walter Reed Army Institute of Research 2023), and the "Southwest Foundation for Biomedical Research" changed its name for the fourth time to "Texas Biomedical Research Institute" (Texas Biomedical Research Institute 2011) in 2011. The Spain Center for Investigation of Animal Health was listed as BSL-4 by the American Biological Safety Association (Tucker 2003), while other sources mention this laboratory as BSL-3 (World Health Organization 2018). These changes in names and status highlight the need for ongoing monitoring of potential activity alteration.

Laboratory accidents are common but may not be disclosed immediately (The Intercept n.d.; Young 2023), such as the 1979 anthrax accident in Sverdlovsk in the Soviet Union (Meselson et al. 1994). Epidemics may originate from pharmaceutical or veterinary laboratories.

For instance, the 2019 laboratory accident related to China's Lanzhou Bio-pharmaceutical plant, which produced brucellosis vaccines, caused more than 10,000 human brucellosis infections (Pappas 2022). However, risk assessment tools that classify natural from unnatural outbreaks do not include biosafety laboratory density or location in relation to the outbreak as a parameter (Chen et al. 2017; Radosavljevic and Belojevic 2012).

Given recent rapid advances in biological technology (MacIntyre 2015), it is important to identify the numbers and locations of BSL-3 and BSL-4 laboratories globally. Considering the historical tendency to deny the unnatural origin of epidemics, including the Rajneesh salmonella epidemic (MacIntyre 2015), the Sverdlovsk anthrax epidemic (Meselson et al. 1994) and the 1977 Russian influenza epidemic (Gregg et al. 1978), mapping BSL-3 and BSL-4 laboratories and correlating emerging outbreaks to laboratory locations can enhance rapid risk analysis of the origin of epidemics (Chen et al. 2024).

In addition, the discovery of unregistered and unlicensed biosafety labs handling dangerous risk level 3 and 4 pathogens to be handled in BSL-3 or BSL-4, lack of a comprehensive list of BSL-3 and BSL-4 laboratories and the

Table 1 Key search terms used to collect BSL-3 and BSL-4 laboratories

Key terms for BSL-3 laboratories	Key terms for BSL-4 laboratories
"BSL-3," "BSL3," "p3 laboratory," "containment level 3," "CL3 laboratory," "High-containment biosafety laboratory"	"BSL4," "BSL-4," "Biosafety level 4," "Maximum containment laboratory/facility," "High-containment biosafety laboratory," "P4," "CL4," "containment level 4 laboratory," "high-level biosafety laboratory"

frequent occurrence of laboratory accidents (Blacksell et al. 2024) with few reports, highlight the urgent need of a global registry and oversight of these high-containment biosafety laboratories. Comprehensive mapping of BSL3/4 labs and applying geospatial techniques to understand potential areas of risk, could improve global biosecurity.

This study aims to map global BSL-3 and BSL-4 laboratories and analyze their relationship to demographic, population, and biosafety data. We provide the most recent and comprehensive global details of BSL-3 and BSL-4 laboratories, using both published and unpublished sources with their specific locations. We also show evidence of gaps in the availability of details of BSL-3/BSL-4 laboratories and variations by national economic, demographic, and biosafety-related characteristics. Such data can help national and international stakeholders enhance oversight and inform improved global biosafety.

Material and methods

Search strategy for mapping of labs

Using specific key terms, we conducted searches to identify BSL-3 or BSL-4 laboratories with known latitude and longitude coordinates. We searched PubMed databases and gray literature sources, such as Google and Google Scholar, and official webpages like the WHO (World Health Organization 2019, 2024), the World Organization for Animal Health (WOAH) (World Organization for Animal Health 2024), the Bioweapons Prevention Project (The BWPP Monitor 2014), the European CDC (European Centre for Disease Prevention and Control 2024), and other biosafety associations as our primary data sources. We utilized the following key terms to search for BSL-3 and BSL-4 laboratories (see Table 1).

In addition to the above key terms, we searched for networks of reference laboratories working with known BSL-3 or BSL-4 agents and their associated networks. For instance, Tuberculosis (TB) is classified as a risk group 3 pathogen, which requires handling in BSL-3 facilities. Therefore, we used national TB reference laboratories as one potential source for BSL-3 laboratories. We also employed a snowballing method to discover additional BSL-3 and BSL-4 laboratories. We also used a list of over 800 labs compiled by DRASTIC (Bostickson 2025).

The above search strategy brings a few lists of BSL-3 laboratories with their details in seven countries compared to the reported numbers: the United States, the United Kingdom, Russia, Japan, Germany, Brazil, Canada, and Australia, which have higher numbers. To ensure a comprehensive list of BSL-3 laboratories with their geolocations, we implemented country-specific searches for the above seven countries and Azerbaijan, Georgia, Ukraine, and Uzbekistan, where our initial search yielded limited results to identify additional laboratories.

The geolocation data (latitude/longitude) for all BSL-3 and BSL-4 laboratories listed was collected through manual searches of the laboratory name from Google Maps. When cataloging laboratories, each organization/facility was counted on the basis of its highest biosafety levels rather than duplicating them as BSL-3 and BSL-4. For instance, if a facility contains BSL-4, BSL-3, and BSL-2 (biosafety level 2) laboratories, it is counted at the BSL-4 level. The same approach was used for BSL-3 facilities.

We created a comprehensive list of BSL-3 or BSL-4 laboratories, including their latitude/longitude location and the pathogens they are known to be working with. For some BSL-3 and BSL-4 laboratories, the specific address was unavailable, so we used the main institution owning the laboratories as the first proxy; if not, the city was used as a secondary option for geolocation data. We used a list of labs identified by the DRASTIC (Bostickson 2025) and cross-referenced with the public map provided by Global Biolabs, which has mapped 69 BSL-4 and 57 BSL-3+ laboratories as of October 2023 report (Global BioLabs 2023). Duplicates were removed by checking names and locations. Initially, we documented 251 BSL-4 laboratories across 34 countries. After validation, 141 duplicates were removed from our database.

Changes in status

Changes in the functional status or biosafety level of BSL-3/BSL-4 laboratories were identified through manual searches of each institution. Some laboratories, such as Texas Biomedical Research Institute, USA, were renamed up to four times; the most recent name was used. Some biosafety laboratories have also changed their biosafety level over time, with BSL-3 laboratories being upgraded to BSL-4 or vice versa. The latest status reports were used. The countries' maximum and most recent number of BSL-3 laboratories from reports/collected data were used to estimate the global epidemiology of BSL-3 laboratories. For the BSL-4 labs' epidemiology, details of their location and the pathogens they are working with were available, and all the analyses related to the BSL-4 labs were on the collected data.

Data analysis

General overview of data analysis

R version 4.3.0 was used for data cleaning, aggregation, standardizations, and estimation of proportions. Using ArcGIS Pro version 3.1, we mapped the number of BSL-3 and BSL-4 laboratories per country and WHO region and summarized their frequency using maps, figures, and tables. As recommended by The World Health Organization, comparing health services by population is a key indicator of measuring health services inequalities (Hosseinpoor et al. 2015). BSL-3/BSL-4 are essential health facilities that indicate the country's readiness for early detection and storage of high-risk pathogen outbreaks. Therefore, presenting ABSL/BSL labs distribution by population can show service inequalities. Additionally, when comparing the epidemiology of BSL-3/BSL-4 laboratories per country, the crude numbers without adjustment for population size or economic indices may mislead readers. Adjusting the count per standard population can give a more plausible interpretation than the crude numbers. Hence, we calculated the rate of ABSL/BSL-3/4 laboratories by population per country.

Rates of BSL-3 and BSL-4 labs per 1,000,000 population were calculated using the 2023 population estimates (Worldometer 2023). National boundaries may not reflect true national delineations, as we relied on names and shapefiles from external reports. We used Equation (1) to estimate the ratio of BSL-3 laboratory to population density per country:

$$Di = (Ni/Pi) \times 1{,}000{,}000 \tag{1}$$

where Di is the ratio of BSL-3 laboratory to population density for country i, Ni is the number of BSL-3 facilities in the country, and Pi is the country population.

Choropleth mapping using graduate colors gives a better visual display with ease of understanding and effectiveness than other thematic mapping methods, such as isoline maps and graduate symbols (Brewer and Pickle 2002; Słomska-Przech and Gołębiowska 2021). Choropleth mapping using ArcGIS was applied to show the locations and density of the BSL-3 and BSL-4 laboratories per country.

Demographic analysis

We normalized country-level BSL-3 and BSL-4 counts by population (2023/24), income level, overall health security index, countries' biosafety, and dual-use research and culture of responsible research. Country-level indicators include countries' overall health security index (%), biosafety, dual-use research and culture of responsible research, and overall risk environment and country vulnerability to biological threats were generated from the 2021 Global Health Security Index report (Bell and Nuzzo 2021). Further working operational definitions and details of selected variables are available in Supplementary Table 1.

Results

We identified 3625 Biosafety level 3 (BSL-3) and Biosafety level 4 (BSL-4) laboratories globally, 3515 of which are BSL-3 and 110 of which are BSL-4, respectively. Details on geolocations and pathogens were publicly available for 955 of these BSL-3 labs.

In total, 110 BSL-4 laboratories were identified in 34 countries. Of these, 45.5% are in the WHO's European region, while the Eastern Mediterranean region has only two BSL-4 facilities (Table 2 and Supplementary Table 2). Details on geolocation and pathogens they worked on were available for all BSL-4 labs.

The Georgia Central Public Health Reference Laboratory, the United States Southwest Foundation for Biomedical Research, and the Kazakh Scientific Centre for Quarantine and Zoonotic Disease Laboratory changed their names (Table 3).

The United States has 17 functional and under construction BSL-4 facilities, the highest number of any country, followed by the United Kingdom, with 13 BSL-4 laboratories, while 17 countries each had one BSL-4 laboratory (Fig. 1).

The BSL-4 laboratories are concentrated in high and upper-middle-income nations. The choropleth map of BSL-4 laboratories shows that high-income countries, such as the United States, the United Kingdom, Germany, and Australia, have more facilities than low-income countries (Figs. 2 and 3).

More than two-thirds (69.1%) of BSL-4 laboratories were from higher-income countries, followed by upper-middle-income countries (22.3%). There are no BSL-4 laboratories in low-income countries (Fig. 2).

BSL-3 laboratories were more frequent and widespread than BSL-4 laboratories. However, the distribution varies significantly, with reports ranging from one to 1643 BSL-3 laboratories per country. The United States (47.1%) and the United Kingdom (17.2%) account for nearly two-thirds of the total BSL-3 laboratories. Others, 58 countries had one BSL-3 laboratory each, 22 countries had two each, eight countries had three each, 12 countries had four each, and 27 countries had at least 10 BSL-3 laboratories each (Supplementary Table 3 and Fig. 4).

Among the 149 countries with at least one BSL-3 laboratory, detailed information about the names, locations, and pathogens they work with is available for all BSL-3

Table 2 Frequency of BSL-4 and BSL-3 facilities per WHO region

WHO region	BSL-4 (*N*)	BSL-4 (%)	BSL-3 (*N*)	BSL-3 (%)
Africa	3	2.7	130	3.7
Americas	31	28.2	1761	50.1
Eastern Mediterranean	2	1.8	30	0.9
Europe	50	45.5	1127	32.0
South-East Asia	7	6.4	106	3.0
Western Pacific	17	15.5	361	10.3
Total	110	100	3515	100

Table 3 Summary of BSL-3 and BSL-4 laboratories with BSL or functionality status change

Facility old name	New name	New BSL	Old BSL	Country	Remark
Georgia Central Public Health Reference Laboratory	Richard G. Lugar Center for Public Health Research (Walter Reed Army Institute of Research 2023)	3	NA	Georgia	Change in 2013
Southwest Foundation for Biomedical Research	Texas Biomedical Research Institute, USA - changed for the fourth time (Texas Biomedical Research Institute 2011)	4	NA	USA	Change in 2011
Kazakh Scientific Center for Quarantine and Zoonotic Diseases (KSCQZD),	Central Reference Laboratory (CRL)	3	NA	Kazakhstan	Replaced (Weber and Pilch 2020)
United Kingdom Chemical and Biological Defence Establishment Center		4 (Tucker 2003)	NA	UK	Closed (The United Kingdom Chemical and Biological Defence Establishment Center 1993)
Center for Genetic Engineering and Biotechnology (CGEB)3, Cuba		4	NA	Cuba	Out of operation (Mafra 2023)
Kharkov. Meref Biolaboratory (Research Institute of Sericulture) and other projects (also called Central Reference Laboratory)		3	NA	Ukraine	Temporarily closed (Badvolf 2024) Page 36
National Biological Laboratory of the 3rd class (BSL-3) in the green zone of Bishkek (Botanical Garden of the Academy of Sciences of Kyrgyzstan).		3	NA	Kyrgyzstan	Closed in 2012 due to community opposition (Badvolf 2024)
Center for Investigations of Animal Health, Spain (Tucker 2003)		3	4	Spain (Peters 2018; Tucker 2003)	
Universidade Estadual Paulista, Campus de Botucatu, Sao paulo Brazil		3	4	Brazil (Tucker 2003)	

NA Not applicable

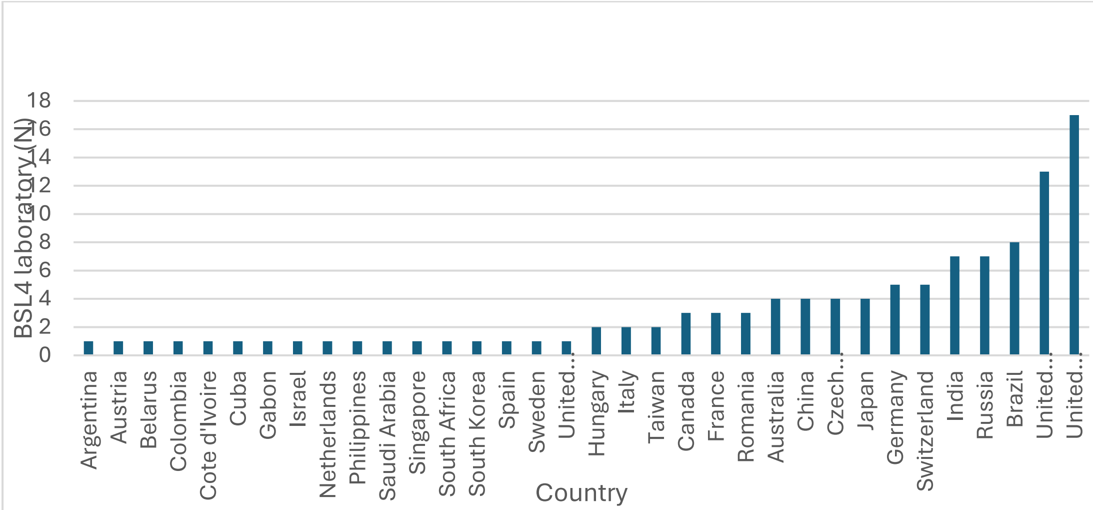
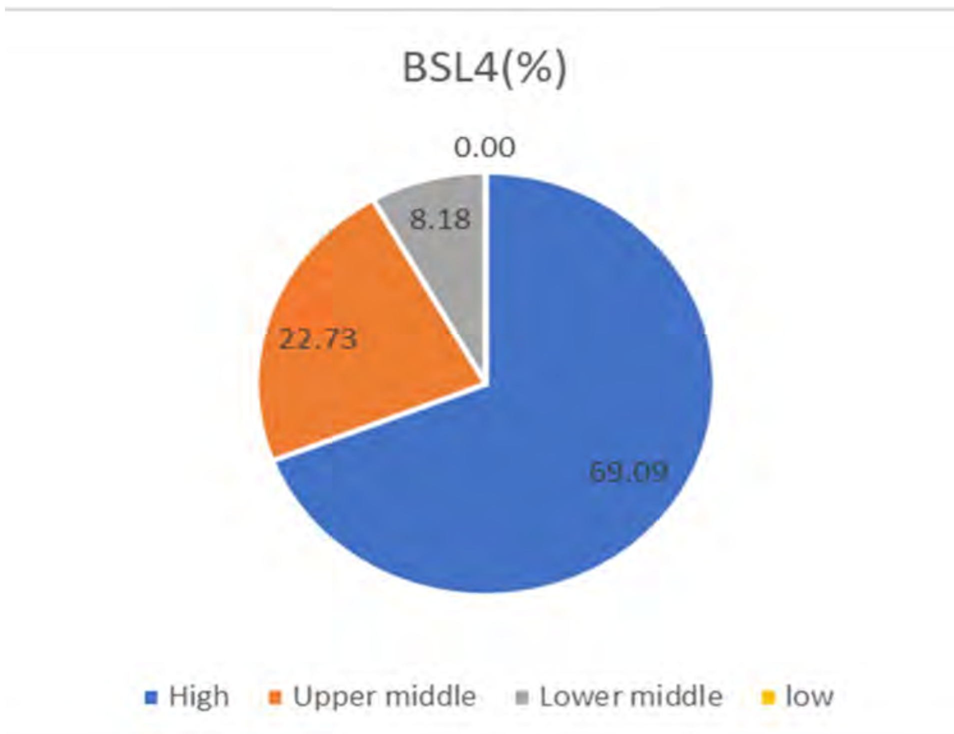


Fig. 1 The number of BSL-4 laboratories per country

Fig. 2 Pie chart showing the proportion of BSL4 laboratories per World Health Organization region ($N = 110$)



laboratories in 118 countries. This information is particularly comprehensive for countries with fewer BSL-3 laboratories (1–4) than countries with a larger number. However, for countries with many BSL-3 laboratories, complete details are unavailable. For instance, Japan and Russia have 200 and 140 BSL-3 laboratories, respectively, but detailed information about the location and names is available for only six and 21 BSL-3 laboratories, respectively (Fig. 5 and Supplementary Table 3).

On the basis of the crude count of BSL-3 laboratories per country, the USA, UK, and Japan had the highest number of BSL-3 laboratories (Fig. 4 and Supplementary Table 3). When adjusting the BSL-3 count per one million population, the United Kingdom had the highest ($N = 9$) BSL-3 rate per a million population, followed by Ireland ($N = 7$), Malta ($N = 6$), and the United States ($N = 5$). In contrast, Bangladesh and the Democratic Republic of

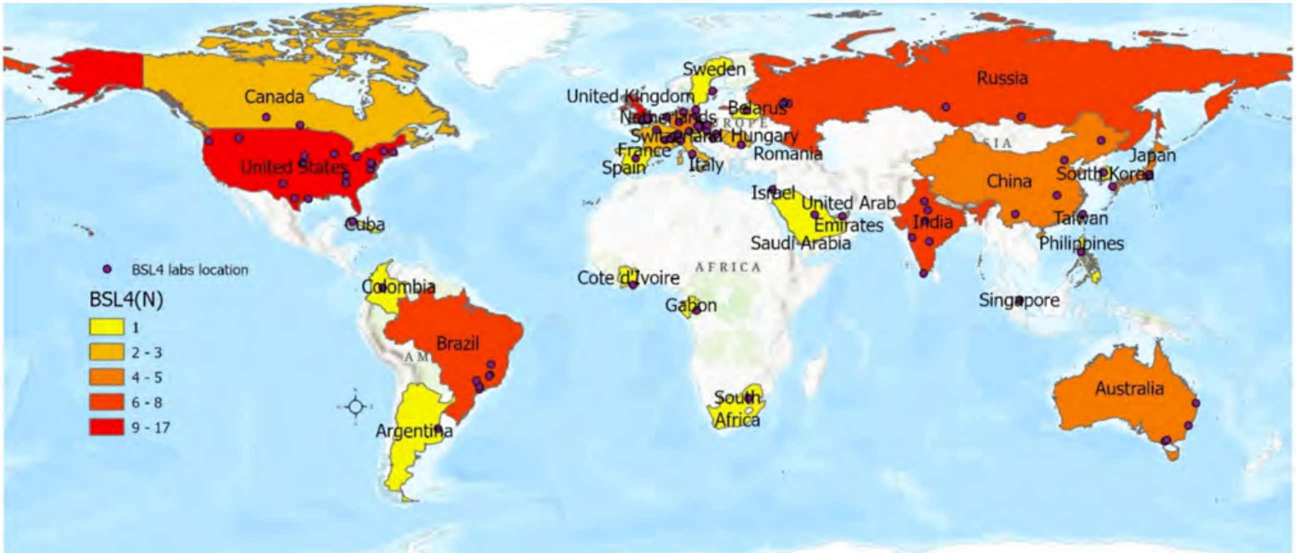


Fig. 3 Choropleth map of BSL-4 laboratories per country. Each dot represents the location of a single ABSL/BSL-4 laboratory, whereas the shaded colors indicate the number of ABSL-4/BSL-4 laboratories with available latitude and longitude locations in each country

Fig. 4 Choropleth map of BSL-3 facilities (N = 3515) per country. The shaded colors indicate the total number of BSL-3 laboratories reported in each country

Congo had the lowest BSL-3 per million population rate compared to other countries (Fig. 6).

High-income countries account for 82.1% (2884/3515) of the BSL-3 laboratories, while low-income countries account for only 1% (Fig. 7)

Countries such as the United States, Canada, Brazil, Australia, and the United Kingdom have a high overall health security index and higher numbers of BSL-3 laboratories. China and India had many BSL-3 laboratories with a moderate overall health security index. While Morocco, Pakistan, Tanzania, and Zambia had a high BSL-3 count but a low overall health security index (Fig. 8).

Globally, 131 countries, with 30.8% of the world's BSL-3 laboratories, did not have any training or regulations related to the oversight of dual-use research and a culture of responsible science (Fig. 9).

More than 3/4 of the BSL-3 labs are in the WHO's Americas and European regions, with 50.1% in the Americas and 32.1% in the European regions. The fewest (0.9%) BSL-3 facilities exist in the eastern Mediterranean regions. When we compare the distribution of BSL-3 labs by income level, most (82.1%) are from high-income countries, while only a few (~1%) are in low-income countries. More than half (N = 77/143, 53.9%)

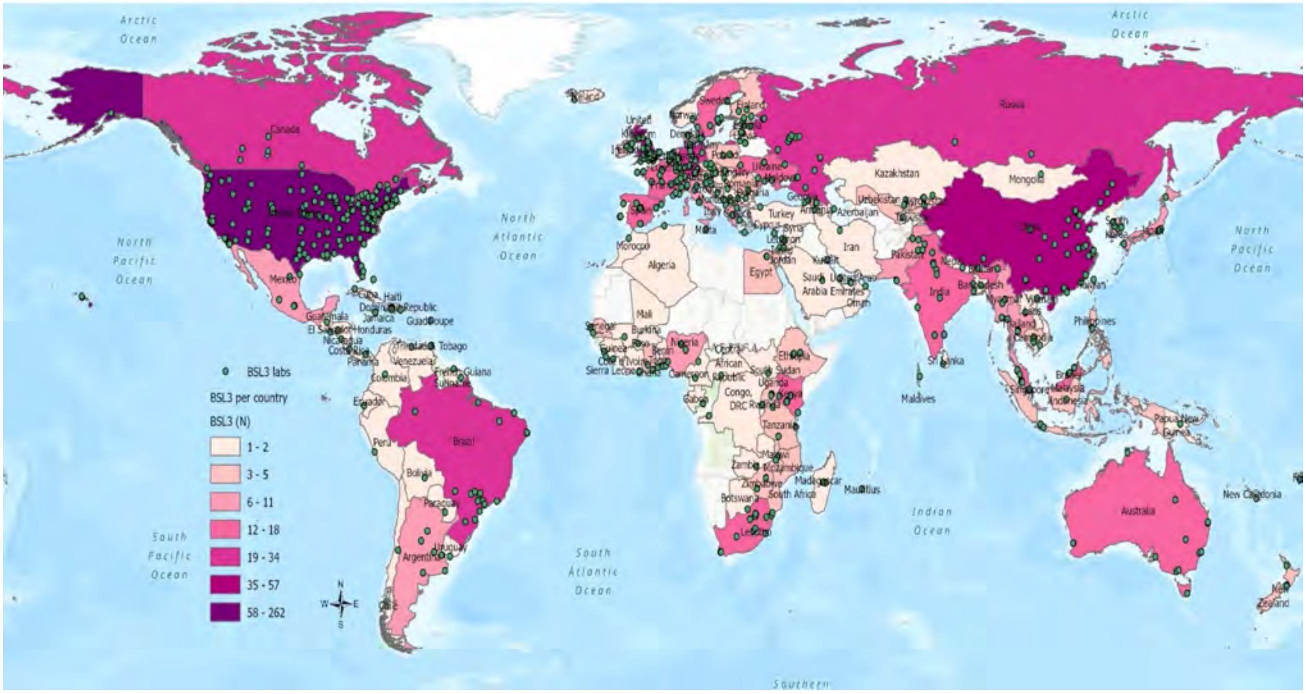


Fig. 5 Choropleth map of BSL-3 laboratories with their details (N = 955). Each dot represents the location of a single BSL-3 laboratory, whereas the shaded colors indicate the number of BSL-3 laboratories with available latitude and longitude locations in each country

Fig. 6 Rate of BSL-3 laboratories per 1,000,000 population, 2024

of the countries reporting at least one BSL-3 laboratory did not have biosafety-related guidelines/regulations or training. Among 34 African countries reporting at least one BSL-3 laboratory, 32 countries did not have any biosafety-related regulation/legislation or training. Regarding dual-use research and the culture of responsible science, 91.6% (131/143) of the countries with at least one BSL-3 lab did not have guidelines/oversight for dual-use research of concern and the culture of responsible science (Table 4).

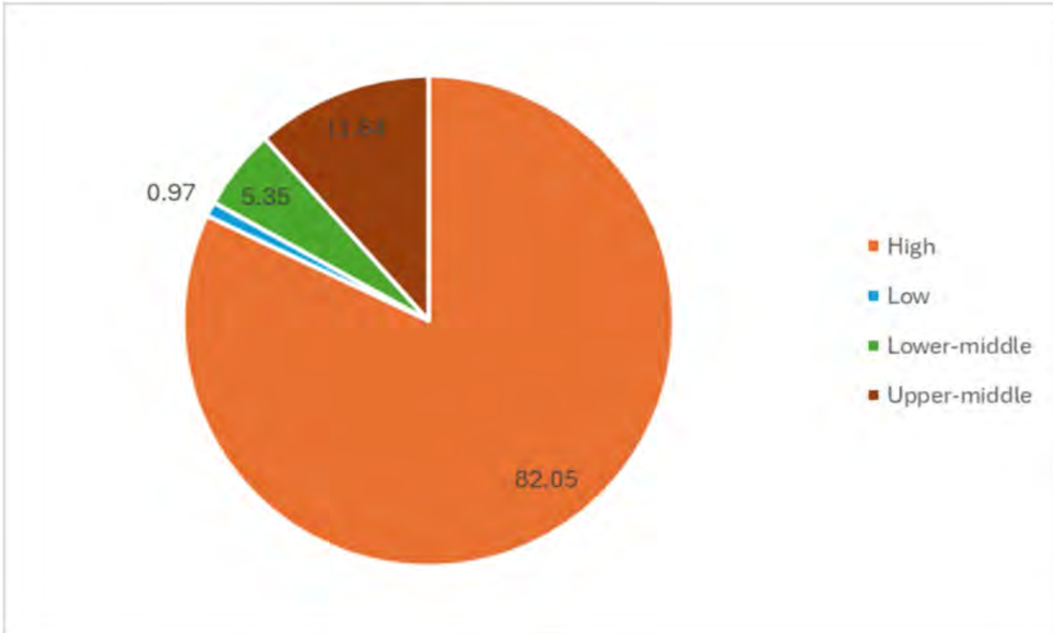


Fig. 7 Pie chart showing the number of BSL-3 laboratories ($N = 3515$) worldwide by the World Bank income level

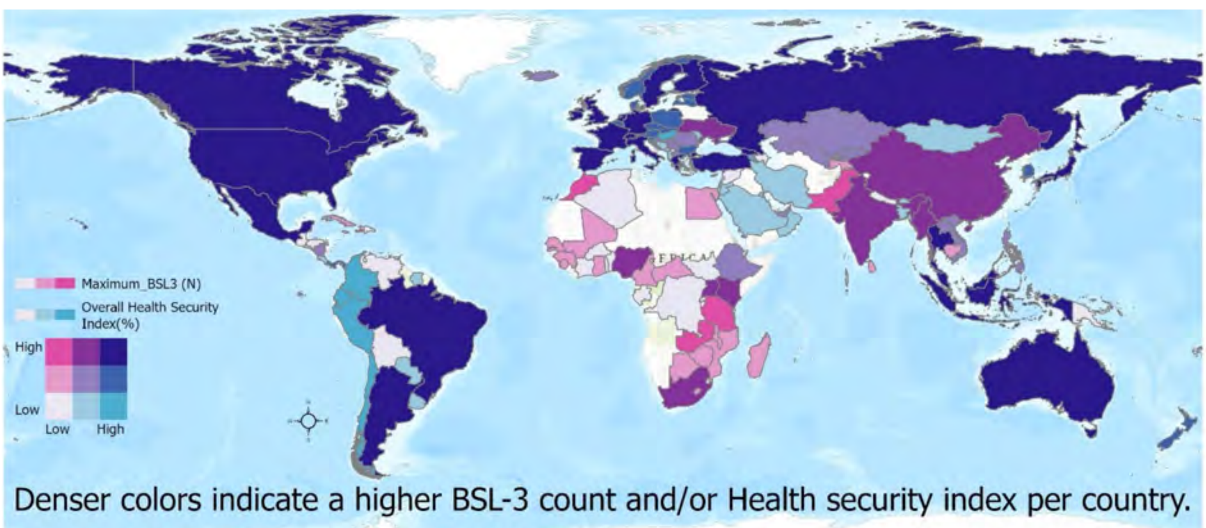


Fig. 8 Bivariable map of BSL-3 laboratories count per country with national health security index. Denser colors indicate high BSL-3 labs or a high health security index in 2024. Pink, purple, and white areas may be more vulnerable in the event of a laboratory accident or mishap

Discussion

We provide one of the most comprehensive maps of BSL-3 and 4 labs globally, to date, and show how mapping such labs can inform global vulnerabilities by a range of indices, including population density, lab density, presence or absence of biosafety regulations and by the Global Health Security Index. A comprehensive, independent geospatial register of BSL-3 and BSL-4 laboratories can provide ongoing capability to improve biosafety, but requires resources to establish, maintain and update. Biosafety laboratories are increasing globally and vary widely geographically, by biosafety regulations and by Global Health Security Index. A key finding was the absence of biosafety regulations or procedures in many countries with BSL3 and 4 laboratories.

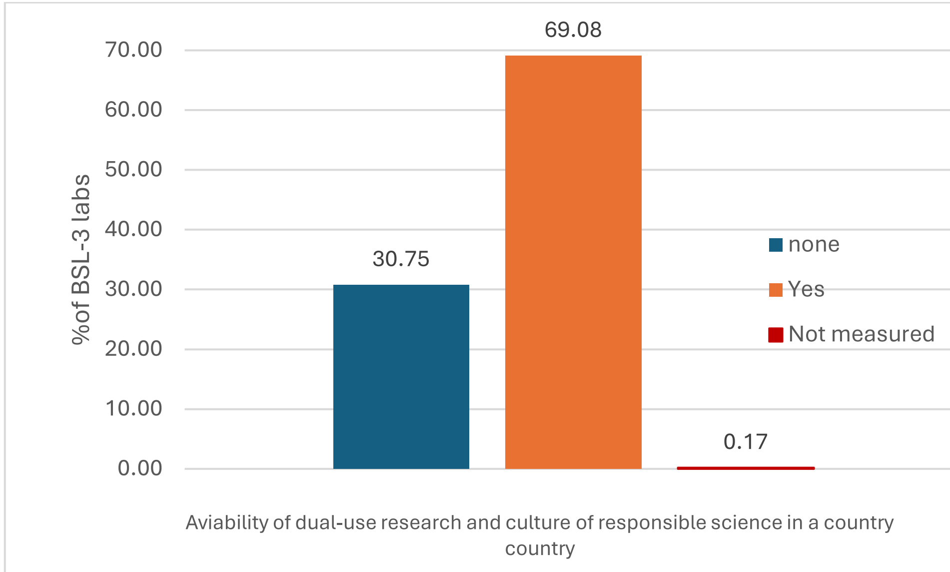


Fig. 9 Bar graph showing the proportion of BSL-3 laboratories ($N = 3515$) by the country's dual-use research and culture of responsible science availability. The legend shows percentage of laboratories from countries with or without dual-use research and culture of responsible science

Table 4 Summary of the global BSL-3 labs and indicators based on the maximum number of BSL-3 labs per country ($N = 3515$)

Parameter	Category	Frequency (*N*)	Proportion (%)
Population per income level	High-income	1,246,088,114	16.29
	Upper-middle	2,762,393,477	36.11
	Lower-middle	3,157,554,072	41.27
	Low-income	484,238,928	6.33
BSL-3 labs by Country's biosafety status			
	Not safe	296	8.42
	Partially safe	1418	40.34
	Safe	1795	51.07
	NA	6	0.17
Countries with biosafety-related guidelines/regulations per WHO region			
Africa (34 countries)	None	32	94.12
	Yes	2	5.88
Americas (28)	None	12	42.86
	Yes	14	50.00
	NA	2	7.14
Europe (50)	None	9	18.00
	Yes	40	80.00
	NA	1	2.00
Western Pacific (17)	None	7	41.18
	Yes	7	41.18
	NA	3	17.64
South-East Asia (9)	None	8	88.89
	Yes	1	11.11
Eastern Mediterranean (11)	None	9	81.82
	Yes	2	18.18
Number of countries with DURC-related training/guidelines	None	131	91.61
	Yes	12	8.39

NA not applicable, health security index related parameters were not measured for some countries

We identified a higher number of BSL-4 laboratories, geolocation, and related details, including planned, under construction, and deactivated biosafety laboratories compared to the 2023 Global Biolabs report (Global BioLabs 2023) and the 2017 WHO consultative meeting report (World Health Organization 2018), which documented 69 and 43 BSL-4 laboratories, respectively. This discrepancy might be attributed to the continuous evolution of new BSL-4 laboratories, such as the National Bio and Agro-Defense Facility (NBAF) in Manhattan, Kansas, USA (News Desk 2023), but also reflects the lack of a global mechanism to keep track of such labs. Since the beginning of the COVID-19 pandemic, six countries, namely Russia, China, India, the Philippines, Taiwan, and the United States, have planned to build 15 BSL-4 laboratories (Lentzos et al. 2022).

While we identified over 3000 BSL-3 and 4 laboratories, we were able to get specific geolocation and pathogen information for only a third of these. This highlights large information gaps. Detailed data were available for 955 BSL-3 laboratories globally, surpassing the 57 BSL-3+ laboratories reported in the Global Biolabs report (Global BioLabs 2023). Such capability can assist when there is war, conflict, or other events which lead to disruption of laboratories and risk to communities. For example, in Sudan and Ukraine, recent conflicts have raised concerns about laboratories being disrupted and posing a biosafety risk (Field 2022; Horton 2023). In addition, lab accidents are common, and understanding the global risk posed by such accidents for communicable disease outbreaks requires knowledge of lab locations (Blacksell et al. 2024).

In two decades from 2000–2021, Blacksell et al. (2024) identified laboratory acquired infections in 309 individuals involving 51 different pathogens, some of which resulted in fatalities, highlighting the importance of biosafety for communities. Economically stronger countries can invest a larger budget in healthcare, surveillance, and response (Papanicolas et al. 2018) and possess robust health services, including better laboratory services, such as BSL-3 and BSL-4 laboratories. For instance, in 2016, the United States spent nearly one-fifth of its gross domestic product on healthcare (Papanicolas et al. 2018). High income countries therefore have a better prospect of mitigating adverse impacts of laboratory accidents.

There are some limitations to this study. We may not have identified all the labs. BSL-2 laboratories may also carry out research that poses a biosafety risk, but identifying and mapping these would be a much larger task, as there are many more BSL-2 than 3 labs. Variations in pathogen risk classification across countries may affect the classification of laboratories' biosafety levels. Some pathogens classified as risk level 3 to be handled in at least BSL-3 labs may be classified as risk level 2 and handled in BSL-2 laboratories in other countries or vice versa. This may underestimate or overestimate the number of BSL-3 laboratories per country. The large gaps in specific information for about 2000 laboratories that we identified is also a limitation and highlights the need for a global register.

Conclusion

We identified and mapped a higher number of BSL-3 and BSL-4 laboratories than past studies. The number of BSL-3 and BSL-4 laboratories is continually increasing, and many do not have adequate biosafety guidelines. Our analysis points to methods for identifying geospatial areas of risk based on a range of factors, including the Global Health Security Index. Mapping and monitoring such labs globally may assist with biosafety and reduce public health threats.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10389-025-02492-3.

Authors' contribution **Atalay Goshu Muluneh (AGM):** did the data curation, visualization, investigation, formal analysis, and project administration and wrote the original draft.

Aye Moa (AM), Samsung Lim (SL), Chandini Raina MacIntyre (CRM): Supervision, Software, Validation, Writing–review.

AGM, SL, and CRM: contributed to the Conceptualization and methodology. All authors reviewed and edited the original draft and approved the final manuscript for submission.

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Declarations

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